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GASDYNAMIC PHENOMENA AND PROPULSIVE PERFORMANCE OF PULSE DETONATION ENGINES

By

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Abstract

In recent decades, the pulse detonation engine (PDE) has been at the center of various propulsion research efforts focused on practical implementation of a reliable detonation-based engine for aerospace propulsion applications. However, many design challenges remain to be solved due to the PDE's unsteady operating characteristics. In particular, the unsteady thrust chamber flow field inherent to the PDE operation makes the design of nozzles aimed at adequately expanding the burned detonation products especially difficult. In order to address this design challenge, this dissertation presents a series of related analytical, numerical, and experimental studies which are focused on investigating the manner in which fundamental gasdynamic processes occurring within the thrust chamber and nozzle flow fields govern the single-cycle PDE propulsive performance. A quasi-one-dimensional method of characteristics (MOC) model with a coupled analytical detonation-contact surface interaction model is developed and validated, and used to parametrically investigate the single-cycle performance of fully- and partially-filled PDEs, and PDEs equipped with diverging nozzles. The sensitivity of thrust chamber flow field to fill fraction and detonable and inert mixture acoustic impedances is studied, and the resulting influence on partially-filled PDE performance is characterized with fundamental scaling relations. Similarly, a detailed parametric investigation of diverging nozzle configurations is conducted to characterize the combined effects of nozzle length, expansion area ratio, and blowdown pressure ratio on the resulting nozzle flow field, and the optimum performance conditions are identified. Lastly, an analytical model is formulated to predict the dynamics of a transmitted shock wave through a general contour diverging nozzle. This model is used in conjunction with the MOC model to investigate the effects of thrust chamber length and nozzle wall curvature on shock attenuation in the nozzle and the overall benefit on nozzle performance.